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ABSTRACT

This paper addresses problems inherent in traditional science teaching and argues that the pitfalls of assimilation and exclusion can be avoided by adopting an anthropological approach: regarding scientists as a sub-cultural group with its own language and ways of thinking about, investigating, and explaining phenomena and events, its distinctive methods for generating new knowledge and solving problems, its tradition, history, set of conventions, and underlying values. Students learn why scientists think and act in these ways, and how they differ from or resemble the practices and traditions of other sub cultural groups. The other element in this approach to science education is the self conscious metacognitive dimension: students knowing that this is what they are doing. More crucially, knowing which aspects to access for particular kinds of activities and encounters, when to use science and how to use it, when to use some other way of knowing. (Contains 27 references.) (Author/YDS)

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# A NEW METAPHOR FOR TEACHING: SCIENCE TEACHER AS ANTHROPOLOGIST

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**Abstract**

This article addresses problems inherent in traditional science teaching and argues that the pitfalls of assimilation and exclusion can be avoided by adopting an anthropological approach: regarding scientists as a subcultural group with its own language and ways of thinking about, investigating and explaining phenomena and events, its distinctive methods for generating new knowledge and solving problems, its tradition, history, set of conventions and underlying values. Students learn why scientists think and act in these ways, and how they differ from or resemble the practices and traditions of other subcultural groups.

The other element in this approach to science education is the self-conscious *metacognitive* dimension: students knowing that this is what they are doing. More crucially, knowing which aspects to access for particular kinds of activities and encounters, when to use science and how to use it, when to use some other way of knowing.

## Border Crossings and Exclusion from Science

Every individual has membership of a number of social groupings, some of which are long-term associations, others of which are merely temporary. Effective participation in these social groups is, of course, dependent on possession of the appropriate cultural knowledge - that is, the shared understandings, beliefs and language, codes of behaviour, values and expectations of the group. Just as each student's personal framework of understanding is unique, so also is each student's complex of social group membership, their perceptions of what that membership entails and requires and, in consequence, their profile of cultural knowledge. When students, each with a distinctive personal and cultural framework of understanding, are presented with a particular learning task set within a distinctive educational context (involving a particular class or learning group), a unique learning context is created for each individual. Appreciation of the uniqueness of personal learning contexts helps to explain why some students learn successfully, while others of supposed equal ability do not, even in apparently very similar circumstances. It helps to explain why particular students may learn on some occasions, but not on others, despite circumstances that to others may seem identical.

Factors that impact on learning include the student's views of school, science and the activities associated with learning science, relationships with peers, teachers and family, learning preferences and other aspects of metacognitive awareness, self-image, aspirations and values. Some are wide-ranging and stable over time; they govern the student's overall attitude and commitment to learning science. Others are topic-specific, even lesson-specific, and influence short-term decision-making about learning behaviour.

For school-age students, the major social groupings of the family, the peer group and the school create distinctive 'social worlds' which may or may not have common cultural knowledge. Phelan et al (1991) suggest that points of similarity and difference between these three social worlds lead to four types of transition into the culture of the school, a transition that is crucial to students' prospects of using the education system to further their life chances and career prospects. Their conclusions are that:

- Congruent worlds facilitate smooth transitions
- Different worlds require transitions to be managed
- Diverse worlds lead to hazardous transitions
- Highly discordant worlds result in transitions being resisted or proving impossible

For science students there is an additional border to cross: transition into the culture of science, or the particular school version of it. School science has its own set of beliefs, values and codes of behaviour. It has its distinctive

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linguistic code. There are many students for whom the rules about the conduct of lessons, the conventions concerning who can speak and what can be spoken about (including what can be challenged), and the particular form of school talk and science talk, constitute a set of conventions and restrictions that are so formidable they are dissuaded even from seeking access to science education. Many students do not see themselves or their experiences, interests, aspirations, values and attitudes reflected in the science curriculum and are uncomfortable with the way it is presented. It is little wonder they decide that science is not for them.

**The Culture of Certainty and Compliance**

Sadly, some of those students who do succeed in entering the subculture of school science are not so much enculturated into the community of science as autonomous individuals as assimilated into a culture of schooling that emphasizes certainty and compliance. Many school science curricula continue to promote the view that science provides a body of fixed, authoritative knowledge about the world arrived at via an all-powerful and all-purpose scientific method. These impressions are reinforced by a heavy reliance on didactic teaching styles and by a style of laboratory work in which students spend considerable time on 'cookbook exercises' designed to reach particular, pre-determined outcomes. As a consequence, students are socialized to see their task as memorizing a series of definitions and reproducing them on demand, mastering a set of algorithms for solving standard problems, and carrying out the teacher's instructions for obtaining a particular set of results. They do not see their role as thinking about or questioning the source, relevance, validity and reliability of the views and ideas presented to them. Nor are they given opportunities to design, conduct and interpret scientific inquiries for themselves and by themselves; they merely carry out the teacher's instructions. Thus, students may succeed in the sense of being able to say and do the 'right things', and can gain the marks available for such conformity, but they fail in the sense of gaining a robust and usable set of meanings to incorporate into a personal framework of understanding. What many students learn is how to do classroom tasks, how to be neat, how to finish on time, how to look busy and to fill up the available time, how to avoid attracting the teacher's attention and, in practical lessons, how to tidy away and write things up in the approved form. What they do *not* learn is how to employ their knowledge in novel situations and how to use it to develop a deeper and richer understanding. Such students have not been enculturated into science, rather they have been assimilated into *school*. They have learned to be compliant students, rather than good scientists and effective learners.

Furthermore, when the curriculum is monitored by the kind of rigid, analytical, objectives-oriented approaches to assessment that are currently in vogue in many places, it becomes an ideal vehicle for those who seek to shape people towards pre-determined goals. It is disempowering because it rules out a concern with critical thinking. Goals are taken on trust; emphasis is on obedience and efficiency in effecting someone else's plans; there is no concern with valuing, criticizing, challenging and changing the goals. By inculcating a willingness to accept prescriptions for behaviour and an acceptance of external control and management, a culture of compliance is created, which impacts adversely on both students and teachers. Education becomes a means of social reproduction, with all its existing inequalities, rather than a means of social reconstruction. When the reward of marks is restricted to the uncritical execution of carefully specified tasks, critique becomes de-valued in the eyes of students, critical faculties atrophy through lack of use and, eventually, students lose all trust and confidence in their capacity to make judgements. Thereafter, decisions on all matters of importance are left to so-called experts.

**Avoiding the Pitfalls of Assimilation and Exclusion**

The notion of science education as enculturation necessitates students crossing cultural boundaries from other sub-cultures into the sub-cultures of school, science and school science. The chances of smooth border crossings are greater when everyone is clear about the nature of the boundaries and the nature of the likely obstacles, and make concerted efforts to overcome them. Thus, it is important that both teachers and students recognize that science itself is a sub-culture, with its own distinctive knowledge, language, methods, rationality, criteria of validity and reliability, traditions and values.

Perhaps the major problem in science education is not that students sometimes have conceptions of phenomena and events that are incompatible with scientific views. Nor that these alternative conceptions are

resistant to change. Rather, the problem is that students have not recognized that they are able to incorporate different aspects of meaning, additional connotations and new relationships into their personal framework of understanding, in order to extend the usefulness and range of applicability of their knowledge, without necessarily giving up their previous, trusted understanding. Not only do we need to ensure that students develop the ability to add to their understanding, we need to ensure that they acquire the second order understanding that includes:

(i) recognizing that alternative conceptions and explanations exist (and alternative methods, too);
(ii) appreciating that the appropriateness and usefulness of knowledge are determined by context;
(iii) knowing what knowledge to access and how to use it in a variety of problem situations and social contexts.

Scientific understanding that cucumbers and tomatoes are fruit, for example, does not preclude the commonsense understanding that they are located in the vegetable section of the grocery store, together with plant roots, tubers and leaves. What is important is recognizing when particular meanings are appropriate and being able to use them properly in the appropriate discourse. There are situations in which the scientific approach has very obvious utility; for certain types of question it can provide a well-tested and powerful answer. In other situations, everyday knowledge is far more useful and appropriate. A central goal of science education is to show students when their own needs and purposes are best served by scientific knowledge and scientific ways of proceeding, and when they are better served by other ways of knowing and acting.

What I am advocating is an approach that recognizes, acknowledges and promotes multiple meanings and multiple perspectives, but ensures that students know which meanings and understandings to access for use in particular circumstances. It is summed up by the phrases "finding one's way around one's repertoire of knowledge" and "having confidence in making an appropriate selection to fit the circumstances". This self-knowledge may be the key to smooth and comfortable border crossings into and out of the culture of school science. Crucial, also, is the capacity to reflect on one's own understanding of these matters and to understand and control one's own learning.

The fundamental point is that one's way of thinking is relative to context and, sometimes, even unique to context - where 'context' includes the physical context, the immediate social context and the wider cultural context, as well as the specific problem context. Since we all move between and among a multiplicity of contexts, we are all capable of holding multiple views about the world. These different perspectives create, for each individual, a complex web of understanding around any given phenomenon or event, which throughout this article I have referred to as a *personal framework of understanding* (Hodson, 1998) and within which students can hold a multitude of diverse and sometimes contradictory views - among them, of course, some entirely erroneous views. Moreover, these personal frameworks of understanding include substantial elements of personal experience, feelings, emotions, attitudes and socioculturally-determined knowledge, beliefs, values and customs.

Extending Giroux's (1992) notion of the teacher as "cultural worker", Medvitz (1997) argues that science can be learned in much the same way as an anthropologist learns another culture. The concepts, procedures and language of science are recognized as cultural artefacts, susceptible to systematic study. They are valid and robust within the cultural context in which they were developed, but sometimes have little relevance or meaning outside it. This 'anthropological curriculum' might usefully be extended to include critical scrutiny of the culture of the school: that is, being explicit about the ground rules of school (codes of behaviour, language use and social norms) and the rationale that underpins them.

## Science Teacher as Anthropologist

The literature of teacher education abounds with metaphors: teacher as broadcaster, teacher as gardener, teacher as tour guide, teacher as police officer, entertainer, and so on. Perhaps there is room for another: *teacher as anthropologist*, or "teacher as culture broker" as Aikenhead (2000) expresses it. It is part of the teacher's job to help students gain an understanding of what, for many, are alien cultures (the subcultures of science, school and school science) and assist them in moving freely and painlessly within and between them (Pomeroy 1994, Aikenhead 1996, 1997; Aikenhead & Jegede, 1999). What is needed is a way of entering the

subculture of science, using its knowledge and procedures to engage in interesting and important tasks, and leaving again with one's sense of self intact. Better still, with one's sense of self enriched by the experience. It seems almost superfluous to say that it is crucial that the science education we provide does not require students to give up or compromise their cultural identity, aesthetic sensibilities or moral/ethical values. When presented with such a choice, many students do not choose science.

> When... students' language and cultural experiences are in conflict with scientific practices, when they are forced to choose between the two worlds, or when they are told to ignore their cultural values... [they] may avoid learning science (Lee, 1997, p.221).

My argument is that students can only understand science properly (that is, at a personal level) if they understand 'where it is coming from' - that is, what its fundamental beliefs and assumptions are. Teaching for personal understanding is not just a matter of providing discrepant events and a clear argument for the validity of a new idea. Students also need to understand the fundamental metaphysical considerations and value positions that underpin scientific knowledge and scientific inquiry - for this, they need explicit teaching about science.

Tyson et al (1997) suggest something similar when they make a case for conceptual change to be viewed through three lenses: an ontological lens (students are looking out at the world), an epistemological lens (students are looking in at their own knowledge) and a social/affective lens. As they say, all three aspects impact on learning and can impede or facilitate border crossings. However, their model is too static and too logical for my purposes. Above all, it is too impatient of culturally-determined differences in worldview: "students have to *stop* thinking of concepts like heat, light, force, and current as material substances" (p400, emphasis added). The approach I am seeking does not equate understanding with belief, nor does it seek to displace other worldviews with the approved scientific view. Rather, it seeks to equip students with the knowledge, self-knowledge and confidence to move freely between different worldviews, accepting each on its own terms and for its own purposes. Ogawa (1995) expresses similar views in his notion of "multiscience teaching": helping students to move comfortably and effectively among personal science (including all forms of idiosyncratic beliefs and explanations for phenomena), indigenous science (the communal beliefs of the specific cultural group to which one belongs) and Western modern science (as promoted through the curriculum). Aikenhead (1996, p.41) develops this idea further.

> Border crossings may be facilitated in classrooms by studying the subcultures of students' life-worlds and by contrasting them with a critical analysis of the sub-culture of science (its norms, values, beliefs, expectations, and convention actions), *consciously* moving back and forth between life-worlds and the science-world, switching language conventions explicitly, switching conceptualizations explicitly, switching values explicitly, switching epistemologies explicitly.

Particularly helpful in this regard, despite being more than thirty years old, is the approach of King and Brownell (1966), who describe the disciplines (including science) in terms of eight characteristics.

- As a community - a corps of competent people with a common intellectual commitment to building understanding.
- As a particular expression of human imagination - an idea that has much in common with Gardner's (1984) currently fashionable notion of multiple intelligences.
- As a domain - each discipline defines and develops its particular sphere of concern and interest.
- As a tradition - a history, comprising the activities, experiences and discourse of earlier practitioners.
- As a syntactical structure - a distinctive mode of inquiry and collection of methods for generating and validating new knowledge.
- As a substantive structure - a complex framework of concepts, laws, models and theories.
- As a specialized language - a form of intellectual shorthand for conveying meaning quickly and accurately, as well as a distinctive form of argument.
- As a valuative and affective stance - an array of fundamental beliefs about the nature of being and a complex of emotional dynamism and aesthetics.

Studying these matters and making them explicit to students involves confronting and dispelling the many distortions and falsehoods about science that are commonly projected by school science curricula. Prominent in this distortion of science are the following ten myths (Hodson, 1999a).

- Observation provides direct and reliable access to secure knowledge.
- Science starts with observation.
- Science proceeds via induction.
- Experiments are decisive.
- Science comprises discrete, generic processes.
- Scientific inquiry is a simple, algorithmic procedure.
- Science is a value-free activity
- Science is an exclusively Western, post-Renaissance activity.
- The so-called scientific attitudes are essential to the effective practice of science.
- All scientists possess these attitudes.

In general, female students and members of ethnic minority groups experience the greatest barriers to successful border crossing into the community of science. Consequently, de-mythologizing science should pay particular attention to dispelling the notion that science is an exclusively European or North American (ie white ethnocentred) and masculine practice, and should address questions about the rationality of science and its correspondence (or not) with other ways of knowing and other 'sciences' (African science, Feminist science, etc) (Hodson, 1999b). The explicit comparison of science with other ways of knowing (philosophy, religion, etc) and with everyday knowing and indigenous science (what Ogawa (1995) calls "multiscience teaching") is likely to prove the principal means of achieving the goal that Jegede (1995) calls "secured collateral learning" – the capacity to pass freely and confidently between different knowledge stores and worldviews as the need arises.

**Becoming More Self-conscious**

As individuals learn more science and more of other things, too, their personal frameworks of understanding become more complex by addition of concepts and ideas (what Hewson (1981) calls "conceptual capture") and by reorganization and restructuring (what Ausubel et al (1978) call "progressive differentiation"). These concepts and ideas can be arranged in a number of different ways, rather like a series of maps can be organized to represent rainfall, population or geographical features. Not only do these maps differ somewhat from person to person, but each of us has an idiosyncratic selection of maps available to us. These maps constitute our personal framework of understanding. Learning which map to choose and how to deploy it effectively in particular circumstances is the passport to smoother border crossings.

Of course, these maps are predominantly linguistic maps. Hence, education in science is, in large part, a matter of (i) acquiring familiarity with the specialized language of science and (ii) using it appropriately, in both its spoken and written forms, for a variety of purposes and in a variety of contexts. Learning the language of science is not just a matter of acquiring a few specialist terms and purpose-built vocabulary items. It involves introduction to, and gaining familiarity with, what Lemke (1990) calls the "thematic patterns" of science: the ways in which concepts and ideas are related within a much broader network of inter-dependent meanings. It also entails getting used to some of the other distinctive features of scientific language: the tendency to utilize universal rather than particularistic meanings; the use of technical terms and symbols in preference to colloquial terms; and the use of familiar everyday words in restricted and specialized ways. A science curriculum can be regarded as successful by the extent to which students can use this language appropriately and can present ideas and findings in the distinctive genres of science, particularly the scientific paper and the laboratory or fieldwork report.

Students will learn the language of science properly only through interaction with someone who is already an expert, and by using it themselves in carrying out authentic scientific tasks. Thus, teachers should model appropriate language use, make explicit reference to its distinctive features, provide language-based activities that focus on them, create opportunities for students to act as autonomous users of the language, and provide critical feedback on their success in doing so. There also needs to be much more *metatalk* (talk about talk), with

teachers explaining why they are adopting a particular linguistic form. Students need to know that while everyday language will suffice on some occasions, a specialized language of science is necessary on others. They need to know the circumstances in which different codes are applicable and they need lots of practice in switching between them. This is one key aspect of what Aikenhead (1996) calls autonomous acculturation: "a process of intercultural borrowing or adaptation in which one is free to borrow or adapt attractive content or aspects of another culture."

Strike and Posner (1992) found that students' epistemological views and attitudes affect and are affected by their learning of science. In particular, "students who did well in physics were more inclined to be realists about physics, to demand consistency in their beliefs, to be empiricists in their views of scientific method" (p.165). They also found that confidence in one's ability to learn physics, approaching learning as a task of understanding rather than just remembering, and valuing learning for its own sake, facilitate and are facilitated by growth in physics competence. Of course, it begs the question of what counts as "doing well in physics" and leaves unanswered the question of what "physics competence" means. Nevertheless, it does point to the importance of studies in the history, philosophy and sociology of science in bringing about better learning of scientific content and attitudes more favourable to successful learning in science. And it does point to the significance of self-awareness in achieving what Munby (1980) calls *intellectual independence*: the capacity of an individual to judge the truth of a knowledge claim independently of other people, and to exercise similar independent judgement with respect to views about science and scientific practice. Kuhn (1989) summarizes such views when she describes those enculturated into science as capable of consciously articulating the theories they hold, knowing what evidence supports them or would refute them, and justifying why they hold those views rather than some other views that might also explain the evidence. In a sense, she says, the scientific expertise that enculturation bestows is rooted in metacognitive awareness of epistemological issues: "thinking about theories, rather than merely with them, and thinking about evidence, rather than merely being influenced by it" (p.688).

What I am arguing is that border crossings are eased by helping students to become more conscious of what is involved in border crossing, by promoting a kind of cultural awareness that involves students understanding the social location of beliefs and practices, acknowledging the context-dependence of most of what they think and do, and recognizing the existence of different modes of discourse, each having a distinctive sociocultural origin. Part of this cultural awareness entails recognizing that science itself is a subculture, with its own distinctive knowledge, language, methods, rationality, criteria of validity and reliability, traditions and values; part entails students reflecting on their personal frameworks of understanding and considering carefully the circumstances in which they came to hold particular views and develop particular skills. The capacity to reflect on one's own understanding and to understand and control one's own learning are further elements in the struggle against assimilation and exclusion. However, the capacity to engage in such critical reflection and the attitudinal commitment that drives it also have to be taught.

## Learning About Learning

With appropriate teacher support, students can construct an understanding of their own learning processes, just as they construct (or co-construct, with teacher support) their own views of the world and their views about themselves. Indeed, Gunstone (1994) reports that even students as young as eight years old can be made "learning conscious". It is widely acknowledged that students who understand their own learning and know how to monitor and regulate it are far more effective and successful learners than those who do not. In general, students who learn to reason about their own knowledge, and to question how and why it fits in with other ideas, are more successful in learning (Linn, 1987). This understanding also influences how students perceive errors in their work - as evidence of failure or as a source of useful information for modifying future actions. Learning how to learn more successfully is also an important key to feelings of control and competence, factors that are essential to good motivation and are at the heart of intellectual independence.

Two points should be noted. First, teachers should employ a wide variety of metacognitive activities, because students quickly routinize any task and may fake good learning behaviour in order to win teacher approval (White & Mitchell, 1994). Second, teacher development must precede that of students. Significant changes in the

metacognitive skills of students can only be achieved by teachers who, themselves, possess appropriate understanding, attitudes and abilities (Baird et al. 1991). Similar demands on teachers accrue from the several other aspects of the approach to science education described in this paper. In adopting this approach, teachers are more than facilitators, organizers, managers and discussion leaders, they also have to be skilled practitioners of science. In order to introduce students to the cultural tools and conventions of the community of scientists, devise learning experiences that are scientifically significant as well as meaningful and interesting for students, and in order to guide, criticize and advise students, and ask and answer critical questions, teachers must have a deep understanding of both scientific knowledge and scientific methods. Moreover, they must have a thorough knowledge of the historical development of science, its social, economic and environmental impact, and the social, moral and ethical issues it raises for individuals and for society. This is a pretty daunting set of specifications, but one that holds out the prospect of a much more professional role for science teachers than many other models of teaching and learning, and one that points to clear targets for both pre-service and in-service teacher education .

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